The FAA's Center of Excellence for UAS Research

ASSURE

Alliance for System Safety of UAS through Research Excellence

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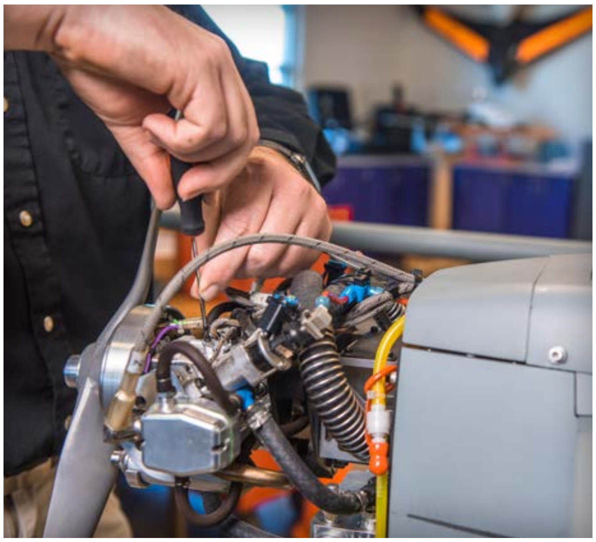
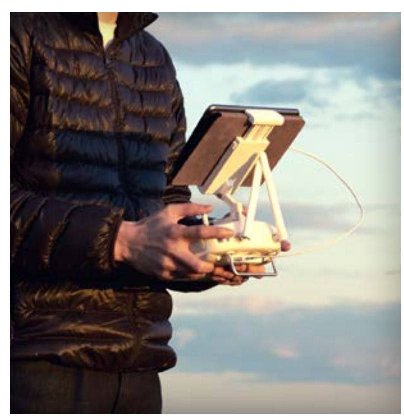
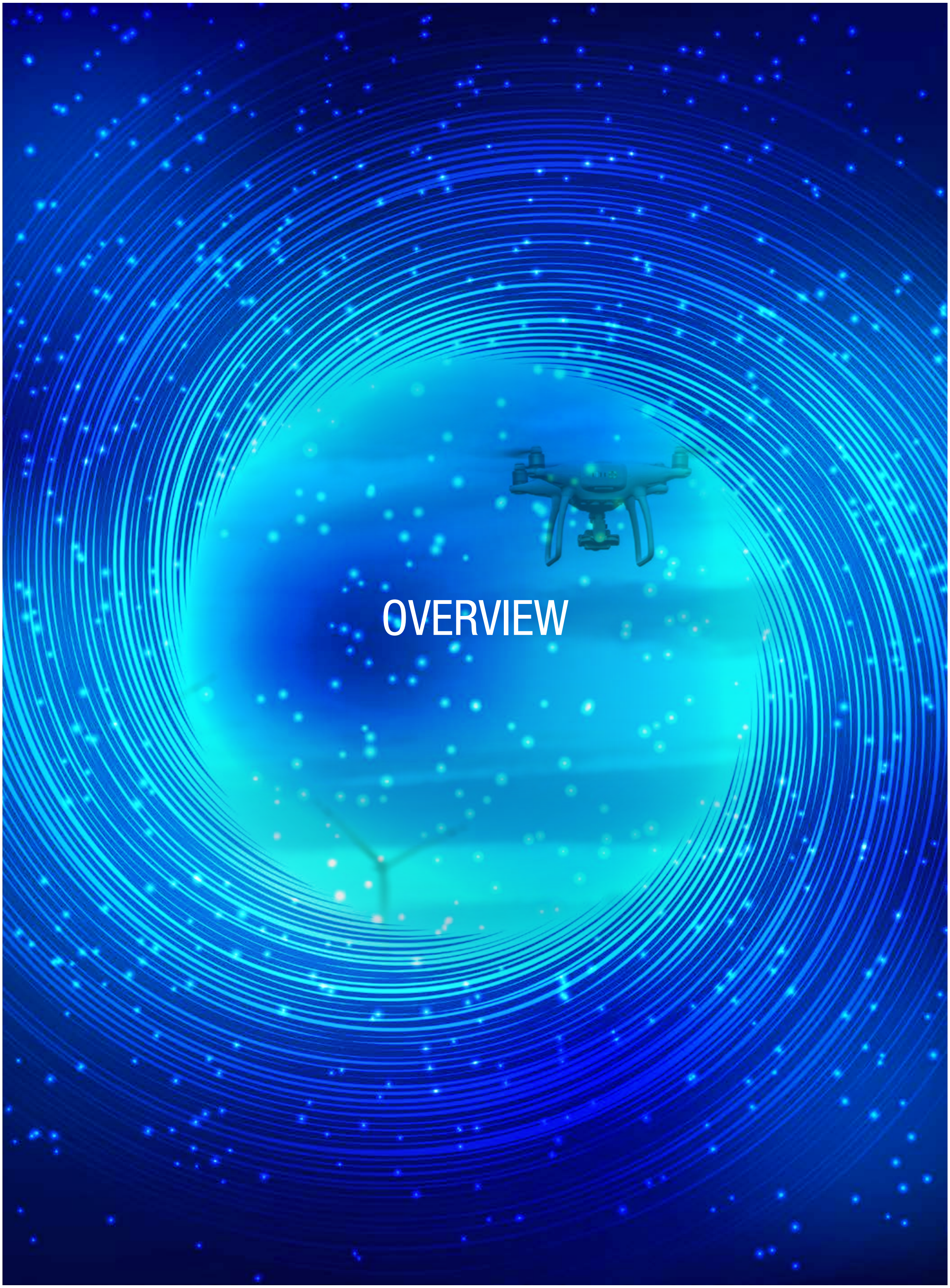
ANNUAL REPORT











OVERVIEW

FOREWORD:

Led by Mississippi State University, 24 world-leading research institutions and over 100 leading industry and government partners serve as the Federal Aviation Administration's (FAA) academic research Center of Excellence (COE) for Unmanned Aircraft Systems (UAS). This coalition, called the Alliance for System Safety of UAS through Research Excellence (ASSURE) features expertise across a broad spectrum of research including: air traffic integration, UAS airport ground operations, control and communications, detect and avoid, human factors, UAS noise reduction, UAS wake signatures, UAS pilot training and certification, low altitude operations safety, spectrum management, and UAS traffic management.

As the ASSURE program finishes our second year of UAS research, we have an opportunity to reflect on the work we've completed to-date and look to the future of the program. As Executive Director of ASSURE, I'm very proud of our accomplishments and how this team has grown together to meet the challenges associated with conducting peer-reviewed research in a consortium environment. It can be difficult for institutions and individuals to subordinate themselves to a large project which encompasses many organizations. In the past year, this team has met every challenge and has provided world-class, peer-reviewed UAS research results to the FAA, better informing the UAS rulemaking process through research data.

ASSURE works to the research timeline established by the FAA in support of the UAS integration roadmap. While many people may not believe full integration, including the ability to conduct regular and reliable safe beyond visual line of sight (BVLOS) UAS operations, is happening quickly enough, our experience has been that we continue to discover nuances and implications to UAS operations that are in many cases codependent and require additional research. These include tracking and identification of UAS, counter UAS operations, reliable command and control links, training and maintenance standards, and many others. ASSURE is working to address these and other issues which directly impact full integration, and we pride ourselves in our fact-based approach of "Informing UAS Policy Through Research."

This Annual Report highlights the work the ASSURE team has provided the FAA and the nation in its second year. Please take a moment to review our work and contact us with any ideas, suggestions, or comments. I am very proud of our team, the research we have completed and that is currently underway, and the tremendous potential of this team to positively impact the safe integration of UAS into the NAS.

MARTY ROGERS
Executive Director, ASSURE

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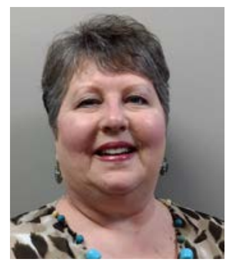


Sheila Ashley
Program Coordinator
sheila@hpc.msstate.edu

MISSION:

Our mission is to provide the Federal Aviation Administration the research they need to quickly, safely, and efficiently integrate unmanned aerial systems into our National Airspace System with minimal changes to our current system.

VISION:

Our vision is to help the unmanned aerial system market grow into its multibillion-dollar market potential by conducting research that quickly, safely, and effectively gets UAS flying alongside manned aircraft around the world.

ASSURE TAG LINE:

Informing UAS Policy Through Research

ACKNOWLEDGEMENTS

Dr. Patricia Watts, National Program Director of FAA Centers of Excellence, Mr. Nick Lento, FAA Program Manager – ASSURE UAS Center of Excellence, and Ms. Sabrina Saunders-Hodge, Director FAA UAS Research Division, have been key to the establishment and success of the ASSURE program. There is a significant amount of education and guidance needed to enable any large team to function and provide optimal results, and Dr. Watts, Mr. Lento, and Ms. Saunders-Hodge have made themselves available to members of the ASSURE team at all times, are always very responsive to our inquiries, and do a great job answering our occasional "what if" questions.

We would not be here today without the vision and leadership of Dr. David Shaw, Vice President for Research and Economic Development at Mississippi State University, who envisioned a UAS COE more than seven years ago, and as he has since the beginning, makes sure the ASSURE team has the resources and strategic guidance to help fulfill our obligations to both the FAA and our partners.

I also would like to acknowledge a team who has gone "above and beyond" in their duties. Without the honest feedback, unstinting support, and positive attitudes of the ASSURE team – Stephen Luxion, Deputy Director; Dallas Brooks, Associate Director; Brandy Akers, Financial Manager – and Sheila Ashley, Program Coordinator – we would not have been successful in meeting our commitments and obligations to our partners and sponsors. Working with ASSURE requires frequent travel, and long days and weekends, and this team gives it all, all the time.

The ASSURE team encompasses almost 150 core, affiliate, government, academic, and industry partners. To acknowledge every member of the several teams involved in the management and execution of the ASSURE mission would not be possible. Support from these partners comes from great people who are experts in aviation, aerospace, human factors, training, maintenance, logistics, operations, finance, and administration, and many who freely give their time every day to ensure the success of this center. A day never passes that I don't think of the tremendous talent and goodwill that makes ASSURE successful, and I'm personally grateful to all our partners and stakeholders.


FINANCIALS

ASSURE FUNDING SUMMARY

Total Funding $11,979,214.59

	Award Amount	Expenditures	Remaining	Cost Share
Program Office Funding	**$2,900,866.52**	**$1,895,467.12**	**$1,005,399.40**	**$1,025,695.26**
Core Schools	**$9,078,348.07**	**$6,607,263.90**	**$2,471,084.17**	**$7,446,079.46**
Drexel University	$559,350.00	$477,186.24	$82,163.76	$474,144.90
Embry-Riddle Aeronautical University	$568,487.00	$503,095.32	$65,391.68	$503,095.32
Kansas State University	$817,491.00	$817,491.00	$0.00	$852,987.95
Mississippi State University	$941,659.07	$592,664.49	$348,994.58	$541,679.98
Montana State University	$391,436.00	$336,403.10	$55,032.90	$385,999.14
New Mexico State University	$900,000.00	$776,891.07	$123,108.93	$713,427.30
North Carolina State University	$229,916.00	$229,876.39	$39.61	$229,876.39
Ohio State University	$1,042,738.00	$894,251.34	$148,486.66	$1,102,884.32
Oregon State University	$75,000.00	$75,000.00	$0.00	$75,000.00
University of Alabama-Huntsville	$1,007,608.00	$307,000.98	$700,607.02	$979,755.81
University of Alaska-Fairbanks	$50,982.00	$2,910.76	$48,071.24	$3,369.40
University of California-Davis	$45,000.00	$0.00	$45,000.00	$0.00
University of Kansas	$92,000.00	$91,967.86	$32.14	$92,000.01
University of North Dakota	$906,448.00	$811,909.35	$94,538.65	$801,242.94
Wichita State University	$1,450,233.00	$690,616.00	$759,617.00	$690,616.00
Totals	**$11,979,214.59**	**$8,502,731.02**	**$3,476,483.57**	**$8,471,774.72**

SUMMARY BY PROJECT

Total Funding $11,979,214.59

	Award Amount	Expenditures	Remaining	Cost Share
Program Management Funding	**$3,233,866.52**	**$2,200,632.99**	**$1,033,233.53**	**$1,249,071.49**
Projects	**$8,745,348.07**	**$6,302,098.03**	**$2,443,250.04**	**$7,222,703.23**
Cert Test Case to Validate sUAS Consensus Standards	$300,001.00	$299,996.00	$5.00	$300,280.00
sUAS DAA Requirements for BVLOS Operations	$799,992.00	$799,658.63	$333.37	$799,944.34
UAS Airborne Collision Severity Evaluation	$1,000,000.00	$1,000,000.00	$0.00	$1,023,424.27
UAS Ground Collision Severity Evaluation	$382,500.00	$382,387.89	$112.11	$409,098.69
UAS Mx, Mod, Repair, Inspection, Training & Certification	$800,000.00	$799,980.23	$19.77	$806,396.81
Surveillance Criticality for Sense-And-Avoid	$781,533.07	$779,040.15	$2,492.92	$779,040.15
Human Factors: UAS Procedures & Control Stations	$750,000.00	$616,889.29	$133,110.71	$594,863.51
UAS Noise Study	$50,000.00	$50,000.00	$0.00	$50,000.00
UAS Secure Communication Links	$330,000.00	$287,412.31	$42,587.69	$629,988.35
Human Factors: UAS Control Station Design Standards	$900,000.00	$773,644.72	$126,355.28	$813,772.38
Part 107 Waiver Case Study	$151,733.00	$151,274.50	$458.50	$184,588.38
Analysis of UAS Detection Technologies	$300,000.00	$126,343.54	$173,656.46	$133,870.44
Ground Collision Severity Phase II Research Plan Review	$7,026.00	$7,026.00	$0.00	$7,026.00
Ground Collision Severity Evaluation Phase II	$2,042,581.00	$225,134.90	$1,817,446.10	$672,067.85
STEM Education Using UAS as Learning Platform (II)	$149,982.00	$3,309.87	$146,672.13	$18,342.06
Totals	**$11,979,214.59**	**$8,502,731.02**	**$3,476,483.57**	**$8,471,774.72**

COST SHARE SUMMARY

Adaptive Aerospace Group, Inc.	$5,897.34
AgentFly Software	$50,000.00
Arlin's Aircraft	$3,000.00
Boeing	$46,235.64
DJI	$8,070.00
DJI Research, LLC	$48,522.80
Drexel University	$235,134.90
Embry-Riddle Aeronautical University	$330,609.60
General Electric	$145,930.48
GoPro	$12,165.60
Honeywell	$30,275.78
Intel	$26,669.60
K.I.M. Inc.	$29,600.00
Kansas Department of Commerce	$152,969.00
Kansas State University	$705,676.95
Keysight Technologies	$566,690.00
Keystone Aerial Surveys	$1,750.00
Kongsberg Geospatial	$40,000.00
Mike Toscano	$147,500.00
Misc. External Match – Industry Funds	$50,835.78
Mississippi State University	$925,527.68
Montana Aircraft	$6,000.00
Montana State University	$307,428.50
New Mexico State University	$713,427.30
North Carolina State University	$914,370.49
North Dakota Department of Commerce	$399,992.00
NUAIR	$20,923.02
Ohio State University	$100,092.09
Ohio/Indiana UAS Center (ODOT)	$233,000.00
R Cubed Engineering	$6,970.09
Rockwell Collins	$4,015.80
Sandia	$2,257.00
SenseFly	$432,574.40
Simlat Software	$147,260.00
Sinclair Community College	$1,934.00
State of Kansas	$96,475.22
The Cirlot Agency	$116,824.90
University of Alabama in Huntsville	$396,712.41
University of Alaska Fairbanks	$3,369.40
University of Kansas Center for Research, Inc.	$92,000.01
University of North Dakota	$291,250.94
Wichita State University	$621,836.00
Total	**$8,471,774.72**

SUMMARY BY SOURCE

Universities	$5,639,370.27
State Contributions	$882,436.22
3rd Party Contributions	$1,949,968.23
Total	**$8,471,774.72**


RESEARCH STUDIES

AIRWORTHINESS

Research Focus Lead: Wichita State University
Deputy Lead: Mississippi State University

Advances in technology have greatly increased the affordability and accessibility of UAS to potential commercial operators and the general public. Accordingly, when the FAA develops and issues regulations that enable the commercial and private operation of small unmanned aircraft systems (sUAS) in the NAS below 400 feet, we can expect a significant increase in the number of aircraft operating in this space. In addition, these sUAS will operate in airspace that puts them in closer proximity to people than conventional aircraft now operate.

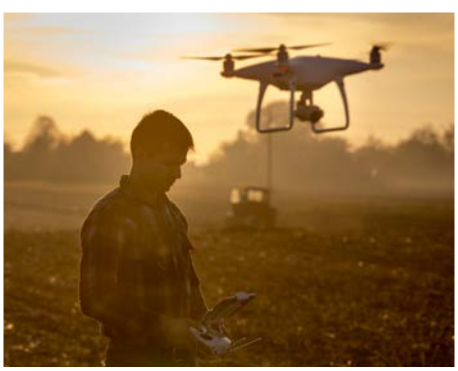
ASSURE Team Capabilities

ASSURE institutions offer metallic and composite material expertise and finite element modeling and simulation capability, including dynamic and crash simulations, as well as aircraft certification experience. They also offer a broad range of test capabilities, ranging from material and structural testing, flight testing, crash and impact testing, wind tunnels, system integration, environmental (DO-160), and propulsion fan blade testing. All institutions have experience working with FAA, DoD and industry.

Research Focus

The ASSURE team is aiding the FAA in defining UAS-related parameters that will allow safe, efficient and effective UAS operation in the NAS by accounting for UAS variations in size, performance and operating environments. Researchers are taking these variations and the practical need for different levels of certification into account. Airworthiness is a broad topic and research includes:

- Definition of structural load processes, loads spectrum, appropriate factors of safety, and methods for proving structural integrity
- Establishment of design and construction standards around material design values, fabrication process controls, hazards to structure and systems/structures interaction
- Development of power plant related criteria for engines, installation and propellers
- Assurance of the environmental suitability of equipment installations
- Determination of conventional certification requirements and probabilistic reliability
- Identification of continued airworthiness inspections, repair standards and operating limitations
- Evaluation of hardware and software tools for UAS certification and safety assessment



Current Research & Results

Certification Test Case to Validate sUAS Consensus

The Federal Aviation Authority (FAA) tasked Kansas Stated University (KSU), in partnership with Wichita State University's (WSU) National Institute for Aviation Research (NIAR), to evaluate the ASTM F38 Standards as a certification basis for small unmanned aircraft systems (sUAS). Throughout this project, the research team analyzed the ASTM F38 standards to identify gaps in the standards as well as compliance issues that manufacturers and operators may encounter when using the standards as a basis for certification through 14 CFR 21.17(b).

One of the gaps identified in previous research was the lack of flight-test requirements for sUAS. As part of Task 1 of the ASSURE A1 statement of work, the research team created an F38-based Flight Test Framework. The researchers determined the resulting framework was insufficient for use, so they conducted a gap analysis to identify areas where the F38 standards were lacking. The team then compiled and delivered a significantly more comprehensive Flight Test Framework as an extension of the original statement of work.

This report provides a summary of the gaps and issues that were identified as part of ASSURE research, shows where the ASTM F38 standards do not adequately address certification flight-testing, and describes the steps taken by the research team to fill in flight test gaps in the ASTM standards. Additionally, this report recommends that the ASTM F38 revise their standards to take certification flight-testing into account; thus, adapting the design and construction (D&C) standards to account for flight-testing as a primary method of compliance. ASSURE researchers documented additional recommendations in the form of a compliance checklist.

The ASSURE research team shared its compliance findings throughout the research project with both the FAA Small Airplane Directorate and the ASTM F38 Committees. In response to this ongoing collaboration, the F38 community is already making improvements to the standards. Most notably, the D&C group has implemented the Flight Test Framework recommendations and is working to create an updated design, construction, and testing standard. The project final report is available on the ASSURE website: www.assureuas.org.


K-STATE
UNMANNED
AIRCRAFT
MOBILE

Name & Origin of All Research Personnel

Name	Origin
Kurt Carraway (PI)	USA
Andi Meyer	USA
Tim Bruner	USA
Tom Aldag (PI)	USA
Kim Reuter	USA
Joel White	USA

Graduation Dates of Students:

Name	Graduation Date
Tim Bruner	December, 2015

Placement of Previous Research Students:

Name	Placement
Tim Bruner	Kansas State University Applied Aviation Research Center

UAS Airborne Collision Severity Evaluation

The purpose of this research was to analyze a small quadcopter and a small fixed-wing UAS configuration impacting on a typical commercial transport jet and a typical business jet aircraft. This research will help determine airworthiness requirements for unmanned aircraft based on their potential hazard severity to other, already certified, airspace users in the NAS. Wichita State University led the research team of The Ohio State University, Mississippi State University and Montana State University that conducted computer simulations of UAS air-to-air collisions and jet engine ingest.

Structural Airborne Collision Approach

Due to the complexity of the problem, full-scale test article availability, time, and budget constraints, the team conducted the R&D effort using National Institute for Aviation Research (NIAR) physics-based Finite Element (FE) modeling techniques, based on the Building Block Approach methodology. This method led research to gain a good understanding of the physics and testing variability from the coupon to the system level.

- NIAR built numerical finite element models for the wing, windshield, horizontal stabilizer, and vertical stabilizer of both a commercial aircraft (similar to 737) and a business jet aircraft (similar to Learjet 31A).
- Likewise, NIAR built a numerical finite element model for the most common “small” UAS (DJI Phantom 3) and researchers from Mississippi State University built the numerical finite element model for a fixed-wing small UAS (Precision Hawk Lancaster Hawkeye III).
- 140 impact scenarios against the aforementioned aircraft structures and with the two different UAS systems were analyzed. These impact scenarios included the most probable high-velocity impact scenarios for aircrafts during landing and taking-off, as well as holding altitude.
- Based on the results the research team developed criteria to help describe the damage levels to the aircraft following an impact (Table 1.)

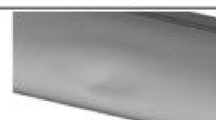
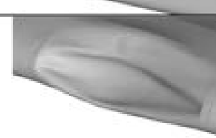
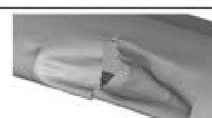
Severity Level	Description	Example
Level 1	• Undamaged • Small deformation	
Level 2	• Extensive permanent deformation on external surfaces. • Some internal structure deformed. • No failure of skin.	
Level 3	• Skin fracture. • Penetration of at least one component.	
Level 4	• Penetration of UAS into airframe. • Damage of primary structure.	

Table 1. Damage Level Categories

Conclusions – Structural Airborne Collision

Commercial Transport Jet: Based on this research, an airborne collision between a commercial transport jet and either a 1.2 kg. (2.7 lb.) quadcopter UAS or a 1.8 kg. (4.0 lb.) fixed-wing UAS at 250 knots may result in a damage severity level of medium-high (3-4) in the horizontal and vertical stabilizer, medium (2-3) in the leading edge of the wing and medium-low (2) in the windshield. Figure 1 below illustrates the impact severity levels at different locations on the commercial transport jet airframe analyzed.

Figure 1. Summary of 1.2 kg. (2.7 lb.) Quadcopter (left) and 1.8 kg. (4.0 lb.) Fixed-Wing (right) UAS Collision Severity Levels on Commercial Transport Jet Type Aircraft

Business Jet: Based on this research, an airborne collision between a business jet and a 1.2 kg. (2.7 lb.) quadcopter UAS at 250 knots may result in a damage severity level of medium-high (3-4) in the horizontal and vertical stabilizer, medium (2-3) in the leading edge of the wing and medium-low (2) in the windshield. Similarly, an airborne collision between a business jet and a 1.8 kg. (4.0 lb.) fixed-wing UAS at 250 knots may result in a damage severity level of high (4) in the horizontal and vertical stabilizer, medium (2-3) in the leading edge of the wing and high (4) in the windshield. Figure 2 below illustrates the severity levels at different locations of the business jet airframe analyzed.

Most of the damage to both aircrafts was caused by the stiffer structural components (motors, battery, camera, etc.) of the UAS. This is consistent with the observations from component level physical testing and numerical analysis.

Figure 2. Summary of 1.2 kg. (2.7 lb.) Quadcopter (left) and 1.8 kg. (4.0 lb.) Fixed-Wing (right) UAS Collision Severity Levels on Business Jet Type Aircraft

Mass: Higher mass UAS impacts resulted in increased damage severity levels in four of the sixteen simulations and more extensive damage for those cases where the damage level classification remained the same.

Velocity: UAS impacts at higher velocities resulted in increased damage severity levels for seven of the sixteen cruise velocity cases. The damage was more extensive at higher velocities even for cases where the severity level remained the same. Slower landing velocity cases showed decreased severity levels in all sixteen cases studied over the baseline, all of them equal or below level 2.

Comparison to Bird Impact: UAS impacts are likely to cause more damage than bird strikes with an equivalent initial kinetic energy (mass and velocity). Since birds behave like a fluid during high velocity impacts, density is the main parameter that drives the magnitude of the damage in the target structure. In contrast, UASs do not exhibit this behavior. Structural rigidity (a combination of the structural geometry and material properties) drives the magnitude of the damage in the target structure. All the UAS impacts shown in this study were associated with greater damage levels than equivalent bird strikes due to the dense, rigid construction of the UAS. Initial motor impact and consequent penetrations exacerbated subsequent impact damage as other high-density UAS components (i.e. battery, camera, etc.) impacted the underlying aircraft structure causing progressively more structural damage, as well as in some cases the UAS ingress into the airframe.

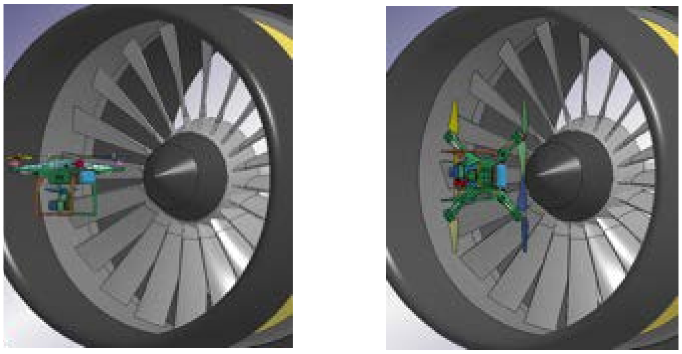
UAS System Architecture: Numerical analysis showed fixed-wing UASs typically caused greater damage levels versus those produced by quadcopter UASs of the same mass and velocity. This indicates that the layout of the main UAS components is critical to the energy transfer during an airborne collision. The predicted critical damage occurs when the majority of the masses were aligned with the impact direction. When the quadcopter UAS was oriented at a yaw angle configuration, 45°, its motor and battery aligned with the impact axis similarly to the fixed-wing configuration; therefore, causing similar damage levels to the aircraft airframe for both UAS architectures.

Engine Ingestion Approach: Currently, there are regulations and engine tests for bird and ice ingestions to ensure a plane can survive impacts with these objects. Researchers and regulators cannot directly transfer past tests and current regulations on birds and ice ingestion to UASs since the materials that compose a UAV are very different from the composition of birds and ice. This research was an initial effort to analyze the effects of two different types of UAS (a small quadcopter and a fixed-wing) into generic engine models of a mid-sized business jet. Understanding the effects of a UAS-engine collision is critical for establishing regulations surrounding UASs, and would provide critical information to better prepare the flight crew if this collision were to take place.

The OSU team developed, in consultation with industry, engine model geometries for two 40-inch diameter fans as reasonable approximations of solid titanium fan blades on the thin side and thick side for the chosen engine size, but were not meant to represent any particular engines in service. The materials used for each of the engine components are reflective of some of the materials currently used in engines and were selected with industry input. Current in-service jet engines differ greatly in geometry and material composition, so the researchers could not develop a single engine model that was representative of all the engines of this approximate size currently in service. The focus of this study is to understand the effect of certain parameters on the damage to the engine and it is not to determine the damage to any specific design.

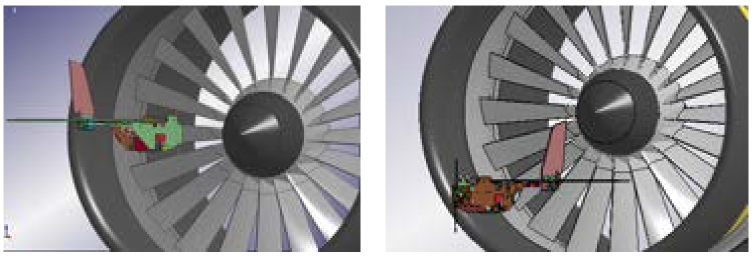
Conclusions – Engine Ingestion

UAS Ingestion Simulations Initial Results: The focus of initial simulations presented in this work were on identifying the critical variables in an ingestion of a UAS. The ASSURE researchers found that the damage from the fixed-wing ingestion is larger than that of the quadcopter ingestion due to its heavier and larger core components, particularly the motor and the camera. A trend observed from both the quadcopter and the fixed-wing ingestions is that the damage increases significantly as the ingestion moves from the center (nosecone), to the inner blade and then to the outer blade. As expected, the takeoff scenario is the worst since the fan has the highest rotational speed in this case. Other factors that have a major impact on the damage level include the thickness of the blade and the orientation of the UAV during the impact. None of the ingestion simulations from this preliminary work resulted in a loss of containment.



(a) Direct (b) 90° Pitch

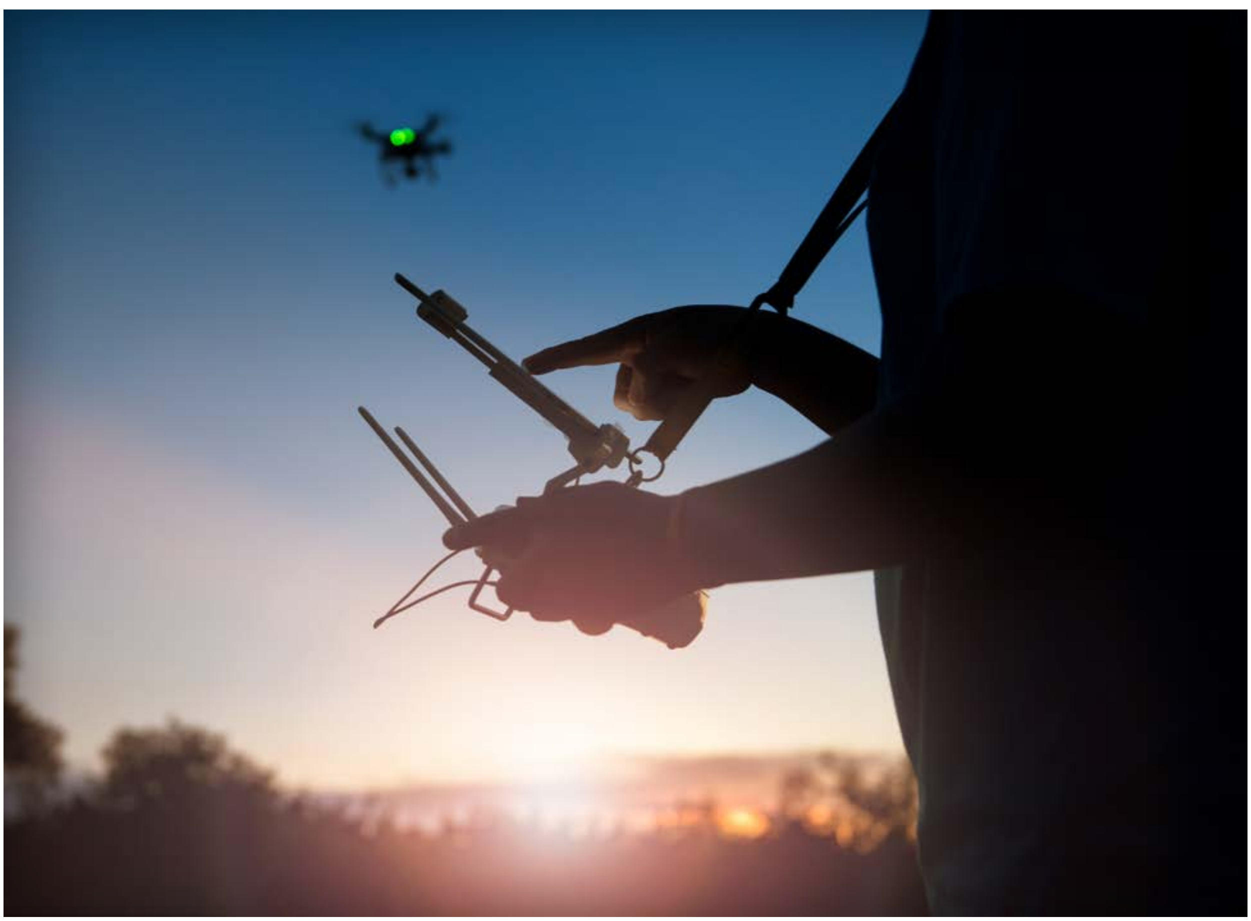
Figure 3. Orientations of Quadcopter Impacts



(a) Direct (b) 180° Yaw

Figure 4. Orientations of Fixed-Wing Impacts

The Air-Collision Severity Studies are available on the ASSURE website: www.ASSUREuas.org. At the time of this writing, the FAA is scoping the next set of studies in this area based on the findings of this study.



Name & Origin of All Research Personnel

Name	Origin
Kiran D'Souza (OSU)	USA
Troy Lyons (OSU)	USA
Erica Johnson (OSU)	USA
Mike Dunn (OSU)	USA
Jim Gregory (OSU)	USA
Thomas Lacy, Ph.D. (Mississippi MSU)	USA
Douglas S. Cairns, Ph.D. (Montana MSU)	USA
Mike Edens (Montana MSU)	USA
Gerardo Olivares, Ph.D. (WSU)	USA
Tom Aldag (WSU)	USA
Chandresh Zinzuwadia (WSU)	Tanzania
Jaime Espinosa de los Monteros (WSU)	Spain
Russel Baldridge (WSU)	USA
Adrian Gomez (WSU)	Spain
Luis Gomez (WSU)	Spain

Graduation Dates of Students

Name	Graduation Date
Troy Lyons (OSU)	May 2020 (Ph.D.)
Erica Johnson (OSU)	May 2018 (BSE)
Kalyan Raj Kota (Mississippi MSU)	May 2019
Trent Ricks (Mississippi MSU)	May 2019
Nimesh Jayakody (Mississippi MSU)	May 2018
Graham Johnson (Montana MSU)	May 2019
Forrest Arnold (Montana MSU)	December 2018
Rodrigo Marco (WSU)	December 2017
Sameer Naukudkar (WSU)	August 2017
Hoa Ly (WSU)	August 2017
Akshay S. Patil (WSU)	December 2017
Nathaniel Baum (WSU)	May 2019
Armando Barriga (WSU)	August 2017
Viquar Hasan (WSU)	August 2017
Obaidur Mohammed (WSU)	August 2020
Ankit Gupta (WSU)	April 2019
Akhil Bhasin (WSU)	August 2020

Placement of Previous Research Students

Name	Placement
Sameer Naukudkar (WSU)	ZODIAC Aerospace
Armando Barriga (WSU)	NIAR (WSU)
Hoa Ly (WSU)	NIAR (WSU)
Viquar Hasan (WSU)	Lear Corporation
Rodrigo Marco (WSU)	NIAR (WSU)

UAS Ground Collision Severity Evaluation

The ASSURE research team of University of Kansas, Mississippi State University, Embry-Riddle Aeronautical University, and led by The University of Alabama in Huntsville, has completed the first phase of research and has delivered its report to the FAA, Congress, UAS Stakeholders and the public. The National Institute for Aviation Research at Wichita State University supported impact testing in support of a separate quick-reaction study. The ASSURE team incorporated results of the quick-look study into this final report. The final report documents the UAS platform characteristics related to the severity of UAS ground collision with people and property on the ground.

Approach: The team conducted a literature search of over 300 publications from the automotive industry, consumer battery market, toy standards, and other fields. The team evaluated proposed space debris casualty models on their viability as a metric and assessment tool for UAS ground collision severity. Researchers conducted parametric analysis, and presented modified methods of analysis that provided new insights on the most significant UAS characteristics and how they relate to the ground collision severity.

Key Findings:

Key mUAS & sUAS Characteristics: The ground-collision study team reviewed the available research and analysis techniques used to address blunt force trauma injuries, penetration injuries and laceration injuries that present the most significant threats to the non-participating public and crews operating sUAS platforms. The most significant of these characteristics related to ground collision severity are:

1) The impact kinetic energy (KE) and impact orientation based upon a *specific vehicle* is the most significant metric for evaluating blunt force trauma injuries. Blunt force trauma is the most likely cause of fatalities due to UAS collisions for mUAS and sUAS, with the exception of single-rotor helicopters, whose blade mass and blade speed present a lethal impact threat. Manufacturers and regulators, through testing, can easily estimate and measure impact KE on vehicle velocity.
2) The energy density parameter is the best metric for evaluating the possibility of penetration injuries caused by sharp edges or small impact areas in the vehicle design. However, this parameter is very challenging to measure during testing. An energy density metric is certainly important for designers to consider in reducing this aspect of injury risk.

3) Rotor diameter is the dominant metric for severity of injury from rotors and propellers for multi-rotors. Regulators can use this metric to define when blade guards or other protective measures are required to prevent laceration injuries (which is the most likely type of injury to occur). Single-rotor helicopter configurations present a potentially lethal threat to the throat and head area due to the blade mass and speed of larger single-rotor helicopters that creates very high rotational energy at contact and potentially lethal blunt force trauma injuries. Rotor diameter is easily measured.

Establishment of mUAS and sUAS Thresholds Other Than RCC: The team investigated and analyzed energy transfer based on actual crash testing and dynamic modeling using finite element analysis for human head and torso impacts. Initial results strongly suggest that Range Commanders Council-based (RCC) thresholds, and therefore, regulatory restrictions, are overly conservative. RCC thresholds do not accurately represent the collision dynamics of elastically deformable sUAS with larger contact areas in comparison to the metallic debris analysis methods for high-speed missiles from which these metrics were derived.

Follow-on Study: Work has already begun. The ASSURE research team includes Wichita State University, Mississippi State University, The Ohio State University, and led by The University of Alabama in Huntsville. Virginia Tech, as an industry partner, will provide consulting support to the project on injury metrics. The ASSURE team will continue to analyze the collisions and test more vehicles to validate findings in their first study. Researchers will validate findings and test techniques against actual human injury to calibrate models and to define appropriate safety margins. The FAA has also asked the ASSURE team to research what an acceptable level of safety should be for the non-participating public and to define a clear and easily repeatable test method to determine the injury potential from the amount of KE that is transferred to a person upon impact by a UAS. This 18-month study should conclude with a public release of findings in the first quarter of CY19.

Name & Origin of All Research Personnel during Original Ground Collision Severity Research

Name	Origin
David Arterburn (UAH)	USA
Chris Duling (UAH)	USA
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Prateek Jolly (MSU)	China
David Francis (MSU)	India
Hannah Stealey (MSU)	USA
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Robert Huculak (WSU)	USA
Marcus, Pyles (WSU)	USA
Andrew Mackey (WSU)	USA
Jonathan Conklin (WSU)	USA
Luis Gomez (WSU)	Spain
Tom Aldag (WSU)	USA
Gerardo Olivares (WSU)	USA

Name & Origin of Research Personnel Working Follow-On Research

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Chris Sallis (UAH)	USA
Clay Colley (UAH)	USA
Stefan Duma (VT)	USA
Steven Rowson (VT)	USA
Mark Blanks (VT)	USA
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Jim Gregory (OSU)	USA
Yun Seok Kang (OSU)	South Korea
Matthew McCrink (OSU)	USA
Ariana Willis (OSU)	USA
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CONTROL AND COMMUNICATIONS (C^2)

Research Focus Lead: Wichita State University
Deputy Lead: Mississippi State University

C^2 research is the development of an appropriate C^2 link between the unmanned aircraft and the control station to support the required performance of the unmanned aircraft in the NAS and to ensure that the pilot always maintains a threshold level of control of the aircraft.

Advanced research is required in datalink management, spectrum analysis, and frequency management. Efforts will focus on completing development of C^2 link assurance and mitigation technologies and methods for incorporating them into the development of standards for the certification of the UAS.

ASSURE Team Capabilities
ASSURE universities have extensive command and control/spectrum experimental facilities that include test aircraft, an indoor compact range, and comprehensive modeling tools.

Research Focus

- Evaluation of C^2 link performance requirements based on current systems, including studying the equivalent performance that may be possible via alternative network infrastructure, such as cellphone networks
- Definition of spectrum requirements for communication, control and surveillance (ADS-B)
- Technical development and standards for secure communications and control links that will be robust to interference (intentional and unintentional)
- Evaluate the capability of passive radar systems for detection of uncooperative aircraft

Current Research & Results

Surveillance Criticality for Sense and Avoid (SAA)
North Carolina State University led a team of researchers from the University of North Dakota, Embry-Riddle Aeronautical, Mississippi State, The Ohio State and Oregon State Universities, and seven industry partners, to determine if UAS using current traffic surveillance technologies, such as transponders, GPS beacons and collision avoidance systems, meet safe separation requirement standards.

Approach: The research team and partners collaborated frequently to include two stakeholder workshops, monthly teleconferences with FAA representatives, and a regular teleconference scheduled among team members. The team conducted a literature review to examine previous DAA-related research, the status of appropriate standards, and to help refine the research approach. The review included product descriptions for surveillance equipment and solutions, published standards, technical standard orders (TSOs), and Advisory Circulars (ACs) for transponders, ADS-B, traffic-collision-avoidance-system (TCAS) II integration, and related technologies. Researchers included evaluations of in-the-field performance and actual monitoring, maintenance/recertification requirements, including effectiveness of controller procedures for altitude/position/speed verification, and pilot procedural altitude/position/speed verification.

The research team used five analysis tools to evaluate airborne surveillance technology performance. These analysis tools included Fault Trees, Monte Carlo Simulations, Hazard Analysis, Design of Experiments (DOE), and Human-in-the-Loop Simulations.

Key Findings:

- Transponder technologies show inherent deficiency for their expected use and are seen as high-risk failures in all airspace and equipage scenarios. ADS-B and TCAS systems are designed to a performance standard that is appropriate in well-controlled airspaces (A, B, and C). However, when outside Class A, B, or C airspace, these systems experience an increase in encounter issues as a direct result of the reduced equipage requirements and the ATC procedures of D, E, and G airspace. Furthermore, the team discovered significant ADS-B and transponder variable performance in fielded systems. The ASSURE team recommends improvements in transponder and ADS-B assurance level to increase the level of the overall safety of the DAA in the NAS. For the UAS DAA systems, the team recommends regulators require that transponders demonstrate more conservative failure characteristics.

- The team's findings on using current surveillance technologies safely for UAS DAA are mixed when applying "equivalent level of safety" expectations. While ADS-B systems in UAS DAA applications show acceptable risk levels in controlled airspaces A, B, and C, manufacturers need to design them to a greater assurance level, in order to use them in lower airspace classes where VFR and non-cooperative traffic are a factor.

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JW Bruce	USA
Michael Wing	USA
Matt McCrink	USA
Jim Gregory	USA
Will Semke	USA

Graduation Dates of Students

Name	Graduation Date
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Nick Allen (UND)	August 2017
Dawson Stott (NCSU)	May 2016

Placement of Previous Research Students:

Name	Placement
Nick Allen	CommDel Industries, Wahpeton, ND
Dawson Stott	CGH Technologies, Washington, D.C.

Secure Communication Links

The current Unmanned Aircraft Systems (UAS) control and non-payload communications (CNPC) infrastructure is susceptible to interferences due to multi-user environment, as well as intentional and unintentional jammers. As a result, a variety of detrimental scenarios can occur. These include data transmission errors, increased power consumption, as well as total loss of link between the unmanned aircraft (UA) and its pilot. Safe and secure communication links require understanding interferences pertaining to UAS and practical mitigation techniques. The Ohio State University (OSU) is investigating these two technological aspects to establish a more secure and robust communications architecture.

Approach: This research involves developing, testing, and evaluating secure communication link schemes relevant to the RTCA Special Committee 228 (SC-228) for Phase 1 Minimum Operational Performance Standards (MOPS).

The ASSURE research team is evaluating and assessing various mitigating techniques such as spread spectrum, adaptive modulation/coding and Multiple Input Multiple Output (MIMO). The team is testing these proposed methods in a simulated multiuser and jamming environment. Researchers are addressing frequency bands relevant to SC-228 Phase 1 MOPS Line of Sight (LOS) terrestrial links. Some considered modulation communication schemes are:

- GMSK (Gaussian Minimum Shift Keying)
- PSK (Phase-Shift Keying) – Constant Envelope versions like OQPSK (Offset Quadrature PSK) or π/4-QPSK
- BPSK (Binary PSK) and QPSK require more amplifier linearity
- FSK (Frequency-Shift Keying) – Continuous Phase versions like GMSK

OSU researchers are conducting physical layer design and tests using software-designed radios (SDR) and hardware implementation of the proposed architectures. The team is conducting tests at the primary frequency band of interest: the C-band (5030-5091 MHz). The team is evaluating the proposed system analytically and is conducting simulations using different software tools for cross verification. To compute coding gain, they examined multiple setups, assuming different modulation schemes (GMSK, PSK, BPSK/QPSK, and FSK). They also investigated the feasibility of spread spectrum modulation given the limited channel bandwidth.

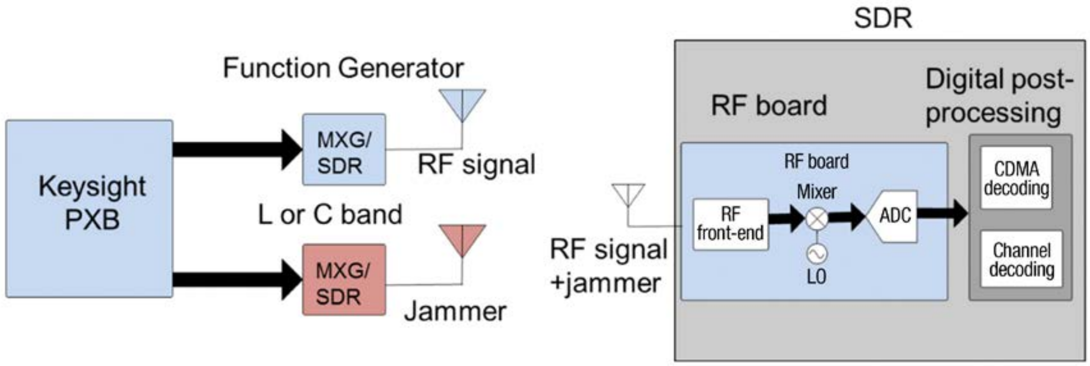
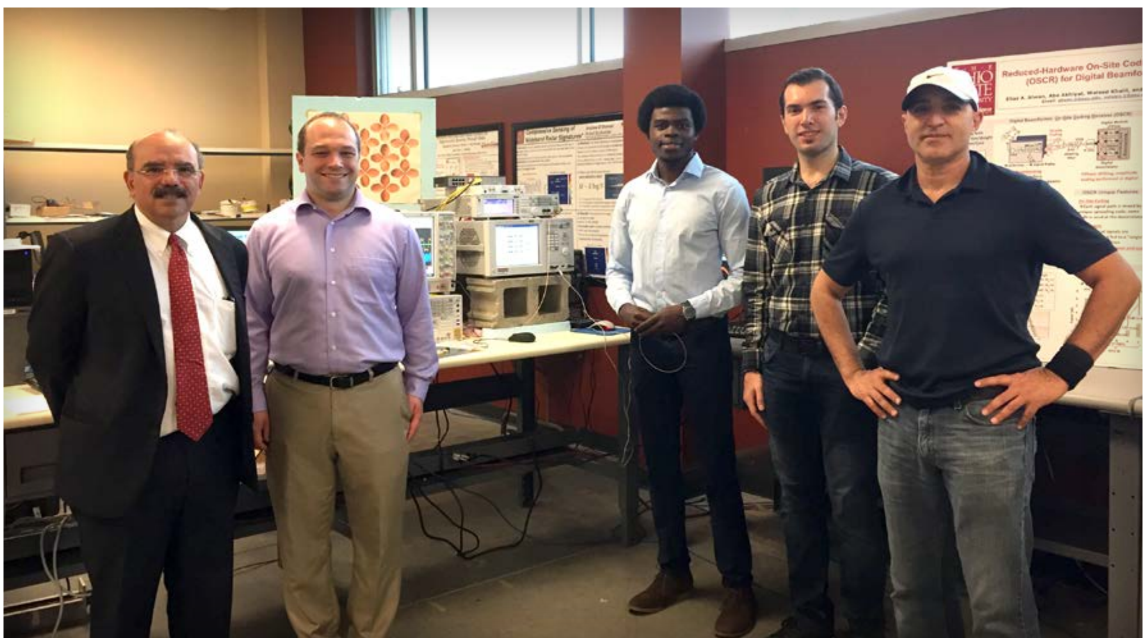


Figure 1. Testbed Architecture

Final Report: The ASSURE research team is completing its work and writing the final report that will be delivered to the FAA at the end of 2017.



Benjamin Bradley (FAA) visits with the team

Name & Origin of All Research Personnel

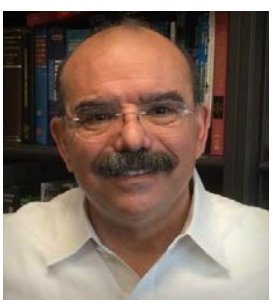
Name	Origin
John Volakis	USA
Emre Koksal	USA
Jim Gregory	USA
Abe Akhiyat	USA
Sam Mensah	USA
Bugra Tulay	Turkey
Hari Indukuri	India

Graduation Dates of Students

Name	Graduation Date
Sam Mensah (OSU)	December 2020
Bugra Tulay (OSU)	December 2021

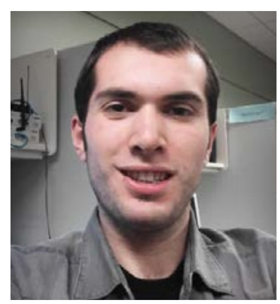
Placement of Previous Research Students

Name	Placement
Hari Indukuri	Expedia, Inc.


John L. Voalkis


Can Emre Koksal


James Gregory


Halit Bugra Tulay


Harihara V. Indukuri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DETECT-AND-AVOID (DAA)

Research Focus Co-Lead: University of North Dakota
Research Focus Co-Lead: New Mexico State University

This research area focuses on issues related to the detection of potential threats to remain well clear of and avoid collisions. It explores sensors, the data produced from sensors, the management and use of that data, and the operational outcome that is considered safe and acceptable.

ASSURE Team Capabilities

The two teaming research institutions offer extensive experience with UAS operations, demonstrated flight test capabilities with the Northern Plains UAS Test Site, and the NMSU UAS Flight Test Site, excellent safety records, and a proven track record with UAS Detect-and-Avoid (DAA) development and testing

Research Focus

- Identify use cases for small UAS (sUAS) Beyond Visual Line-of-Sight (BVLOS) operations
- Develop an operational framework that defines the environment and conditions under which the recommended requirements will enable sUAS operations BVLOS
- Perform approach comparisons for relevant technologies including ground-based and/or airborne approaches that comprise potential sUAS DAA systems
- Flight test performance of selected systems and component technologies based on technology maturity, cost and size, weight and power limitations of sUAS

Current Research & Results

Small UAS DAA Requirements for BVLOS Operations

The Federal Aviation Administration (FAA) tasked the UND and NMSU team to study Beyond Visual Line of Sight (BVLOS) for small unmanned aircraft systems (sUAS, which weigh less than 55 pounds). BVLOS is an operating environment where the sUAS is out of sight due to distance and the limitation of the human visual system. A report capturing a number of elements explored by the team was completed and provided to the FAA. The report is available on the ASSURE website: www.ASSUREuas.org.

To start, the ASSURE research team gathered use cases to assess potential BVLOS applications requiring DAA through a variety of data calls. The team received 40 responses through this process, mostly in the area of mapping, land/area monitoring, and linear inspections. Use cases reported operating altitudes between 50 and 700 feet AGL, with the most typical operating altitudes between 50 and 100 feet AGL. Use case airspeeds ranged between 6 and 33 knots, with an average speed of around 12 knots. No use cases reported actual in-flight climb or descent rates.

To supplement these data, researchers reviewed approximately 5,000 333 Exemption Holders from the FAA. Each of the several thousand 333 Exemption Holders was emailed to request additional information. From these data, the team was able to create categories and subcategories of defined use cases. The ASSURE team also detailed the types and different platforms requested in the 333 exemptions. The total number of use cases was 36,826. Most applications were for 4-copters (total of 6,586), followed by a similar number of requests for fixed-wing (818), 6-copter (726), and 8-copter (879). There were 153 different 4-copter platforms requested and almost 200 different manufacturers in this space.

To ensure safe BVLOS operations and connectivity, the ASSURE researchers tested and assessed actual Radio Line of Sight (RLOS) against that of various RLOS models. Researchers modeled propagation using the well-respected Longley-Rice Irregular Terrain Model (Longley and Rice 1968), which the U.S. Department of Commerce developed in 1968. The team also compared a simplified mathematical model based on a version of the Longley-Rice model, and an online-based Longley-Rice model to actual field measurements to assess validity of the simplified input tools.

The results of the field test indicate that the simplified model and the online calculator models provide too coarse of estimations of RLOS coverage. As the simplified model assumes a uniform terrain type (plains, hilly, mountainous, etc.), it cannot adequately account for a radio coverage area that spans multiple terrain types. This field-testing has demonstrated that real-world RLOS conditions differ from the analytical models – while the mathematical models may attempt to replicate ideal conditions, site-specific influences can affect actual link distances. With the uncertainties shown, it is logical to choose a conservative approach in selecting a safe-and-reliable RLOS operational distance.

The ASSURE team presented its recommendations for an Operational Framework that defines the environment and conditions that enable safe sUAS BVLOS operations. The elements of this Operational Framework result in potential constraints on the systems and operations. The three elements of significant interest are (1) the conditions or locations in which one flies must be conducive to safe flight operations; (2) the operator must operate in a safe fashion; and (3) the aircraft must be capable of reliable and safe BVLOS operations. The Operation Framework provided was not prescriptive, nor did it include an exhaustive set of actions, but the framework included strategies that can build upon FAA and industry actions that should result in an increase in BVLOS flights in the near term. Primary strategies and recommendations to help facilitate sUAS BVLOS operations in the National Airspace System were provided.

ASSURE researchers conducted simulations of sUAS encounters with manned aircraft to test the Science and Research Panel (SARP) definition of “well clear” distances (2,000 ft. horizontally, 250 ft. vertically) and found:

- When the horizontal distance for well clear is expanded to 4,000 ft., advantages are realized in the reduction of Near Mid-Air Collisions (NMACs). With the increased distance, there is more time to maneuver, based on sensor detecting a threat.
- Field of View (FOV) has a significant impact on maintaining well clear. The team recommends a 180° FOV, and a full 360° FOV may be required to handle manned-overtaking-unmanned scenarios.
- The UAS autoflight system must be considered part of the total DAA package. Any autopilot expecting human-in-the-loop control must be capable of aircraft trajectory changes with as few control inputs as possible. The capacity to respond rapidly significantly enhances the ability to maintain well clear.
- Update rates of sensors should be considered when evaluating sensing distance required to enable maintenance of well clear.
- Using a 1 Hz sensor update rate, a 2,000 ft. well clear distance could be maintained when the simulated sensor range was 1.75 nm. For a 4,000 ft. well clear distance, the required sensor detection range is 2.6 nm for a fixed-wing unmanned aircraft (UA) and 3.5 nm for a multi-rotor UA.
- Additional challenges associated with maneuvering vertically to maintain well clear include: ballooning past 500 ft. AGL when operating the UA manually, the threat of crashing into the ground if applying a rapid descent while in manual control, and the inability to remain vertically well clear with a simulated multi-copter while under waypoint control owing to the slowness of the maneuver.

The team also gathered information regarding various sUAS DAA approaches through a literature review, requests for information, and direct interactions. Researchers defined DAA system architectures according to three primary characteristics: sensor location (on/off board), degree of autonomy, and sensor type (active/passive). The researchers then developed metrics to score the different DAA approaches. This process produced the following results:

- Only 11 DAA-intensive companies identified, underscoring the relative youth of this field.
- The majority of DAA-intensive companies are pursuing on-board solutions.
- Companies are only pursuing radar as the off-board solution. Other approaches are in earlier stages of development.
- Companies are pursuing active radar, passive EO/IR, and passive acoustic as on board solutions. Of these, radar and EO/IR are the most popular approaches.
- Off board radar-based systems have advantages regarding sensor performance (e.g., range), with the primary barrier being acquisition cost.
- On board radar-based systems have utilization advantages (e.g., cost, installation), with the primary challenges being detection range and FOV within Size Weight and Power (SWaP) limitations.
- On board EO/IR-based systems provide excellent update rates and may provide utilization advantages (e.g., cost). However, FOV and SWaP appear to be challenges.
- On board passive acoustic approaches appear to enable a complete FOV, with comparable range performance at an apparently lower SWaP requirement.
- Flight-testing would enable both characterization of approaches and establishment of standards that will enable future system development.

Finally, the ASSURE team assessed risks by focusing on the Safety Risk Management (SRM) pillar of the SMS (Safety Management System) process. This effort (1) identified hazards related to the operation of sUAS in BVLOS, (2) offered a preliminary risk assessment considering existing controls, and (3) recommended additional controls and mitigations to further reduce risk to the lowest practical level. Within both ground and airborne-based DAA systems, hazards generally coalesced into four components (1) Level of Autonomy, (2) Hardware, (3) Software, and (4) Sensor. Researchers identified the risks for nearly 250 hazards and offered some degree or method of mitigation. Implementing recommended mitigations and controls resulted in:

- For autonomy – reduction to 2 high risks, 13 medium risks, and 10 low risks.
- For hardware – reduction to 1 high risk, 1 medium risk, and 59 low risks.
- For software – reduction to 1 high risk, 5 medium risks, and 49 low risks.
- For sensor – reduction to 20 high risks, 34 medium risks, and 78 low risks.

The team identified common mitigations that include practical performance evaluation or equivalent, more stringent medical standards than those established under 14 CFR §107.17 for crewmembers operating sUAS BVLOS, system redundancy, and health monitoring of flight critical processes. The challenges associated with Software Of Unknown Pedigree (SOUP) surfaced repeatedly across the software component, with the frequent mitigation being to adhere to standards such as DO-178. The application of DO-178C as an existing control generally resulted in residual risks having the lowest likelihood of occurrence but commonly high severity owing to the presence of single point events/failures. The researchers did note that the go-to-ground/land mitigation provides an overarching mitigation for alleviating unacceptable residual risk, but may come with its own challenges as to public trust and creating other risks.

Name & Origin of All Research Personnel

Name	Origin
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William Semke (UND)	USA
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Ron Marsh (UND)	USA
Hassan Reza (UND)	USA
Douglas Olsen (UND)	USA
Chris Theisen (UND)	USA
Scott Kroeber (UND)	USA
Trevor Woods (UND)	USA
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John Nordlie (UND)	USA
Michael Mullins (UND)	USA
Kyle Foerster (UND)	USA
Rosa Brothman (UND)	USA

Graduation Dates of Students

Name	Graduation Date
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Rosa Brothman (UND)	December 2017

Placement of Previous Research Students

Name	Placement
N/A	N/A

Performance Analysis of UAS Detection Technologies Operating in Airport Environments

The steep increase in reports of small-unmanned aircraft (UA) in close proximity to airports and manned air traffic is presenting a new challenge for the FAA. The safety of the NAS is the Agency's responsibility including identification of possible gaps in safety and addressing them before a significant incident occurs.

The ASSURE COE team, the University of North Dakota and New Mexico State University, led by Mississippi State University, is performing post-analysis of data after Airport demonstrations to identify the capabilities, performance characteristics, and limitations of specific instances of UAS detection technologies to assess which technologies demonstrate applicability and/or promise for use in and around the airport environment. This assessment examines strengths and weaknesses between technology types; how those technology types might perform in differing environments; and the potential for combining multiple technologies into a layered solution.

Gryphon Sensors Skylight UAS Detection System (Assessed at DFW)

In addition to the technology assessment, the research team is finalizing a literature review of related testing activities conducted by other government agencies to inform the FAA of the current state of the art for UAS detection, identification, and tracking. The review served to inform the assessors of technological approaches for detection system evaluation conducted by other agencies, including the Departments of Defense, Homeland Security, Justice and Energy.

As of this report, the team has completed its unclassified literature review and provided some "quick-look" findings regarding one vendor's system's performance in flight tests performed at the Dallas/Fort Worth International Airport (DFW) to the FAA. The flight tests evaluated the system against an array of representative systems provided and flown at DFW by the Lone Star UAS Test Site.

Representative UAS Systems Flown During the DFW Evaluation

The final report, which will incorporate post-event data analyses from previous FAA-sponsored evaluations conducted at Denver International Airport, New York's John F. Kennedy International Airport, and the Atlantic City International Airport, should be delivered to the FAA and available to the public in the 3rd Quarter of fiscal year 2018.

Name & Origin of All Research Personnel

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Scott Kroeber (UND)	USA
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Graduation Dates of Students

Name	Graduation Date
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Taylor Trask	Spring 2019

Placement of Previous Research Students

Name	Placement
Alex Butland	Graduate Student

HUMAN FACTORS

Research Focus Lead: Drexel University

When the pilot controls the aircraft from a remote control station, several human factors issues emerge with respect to the pilot, the air traffic controller, and their interactions to safely operate UAS in the NAS. Human factors issues in manned aviation are well-known, but further analyses regarding integration of UAS into the NAS is required.

ASSURE Team Capabilities

ASSURE capabilities include human factors engineers and scientists, human-in-the-loop simulation and training environments, and associated design and evaluation tools. The team applies theory, principles and methods to consider human performance and limitations to address human factors safety concerns that are unique to UAS operations, and to inform the development of standards, regulations and guidance for civil UAS.

Research Focus

- Support the development of regulatory and guidance material related to ground control stations (GCs), ground observers and pilot certification and training
- Support the development of minimum information requirements and best practices to ensure safe integration of UASs into the NAS
- Support the evaluation of potential safety issues with the GCS, including that UAS GCS buildings and trailers are safe for pilots and crew
- Support the development of recommended crewmember training and certification requirements, to include pilots and other crewmembers
- Support the development of recommended UAS crewmember procedures and operational requirements

Current Research & Results

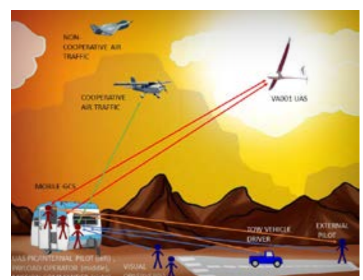
UAS Human Factors Control Station Design Standards (plus Function Allocation, Training, Visual Observer)

Drexel University is leading a team of experts from New Mexico State, The Ohio State University, University of North Dakota, and Montana State University to provide recommendations for minimum human-automation function allocation strategies, minimum information requirements, crewmember training and certification, and visual observer training and certification for fixed-wing unmanned aircraft (UA) larger than 55 lbs. The analysis includes transition to/from IMC while the UA is within the visual observer's (VO) visual line of sight limit.

<u>Function Allocation:</u> The researchers developed a minimum function allocation framework to guide the work. A task analysis of aviate tasks (climb out, cruise, descent, and approach phases of flight) guided the function allocation analysis. For each task, the researchers identified a recommended functional requirement as well as a minimum human-automation function allocation recommendation. The team provided rationale for the recommendations including potential safety implications. The team included potential higher and/or lower levels of automation including an autonomous-mode function allocation recommendation in the event of lost control link.

The work was refined via feedback from nine Subject Matter Experts (SMEs) with experience in varying roles of unmanned and manned-aircraft operation, including but not limited to remote pilot in command (RPIC), control station designer, manned/unmanned flight instructor, manned/unmanned test pilot, certified pilot, and RPICs with UAS research experience. Researchers asked the SMEs to consider what automation is necessary to compensate for any human factors implications associated with operating the aircraft remotely. To help provide some context, the research team asked SMEs to consider typical flying conditions. ASSURE researchers incorporated SME feedback into the recommendations.

Several overarching themes were prevalent in the SME feedback. Overall, pilots can safely aviate the UAS with minimum function allocation strategies similar to those for manned operation (i.e., substantial automation assistance is not required compared to manned aircraft operation). This recommendation assumes, however, timely and accurate delivery of information to the UAS control station.



Information Requirements: Members of the team conducted a control station literature review composed of the Code of Federal Regulations (CFRs), incident and accident reviews, human factors UAS literature, and select fielded and research operational control stations. The team created two taxonomies to categorize information elements: one reflecting the level of availability of the information element, and one identifying the agent(s) with control over changing the information element. Researchers leveraged the literature review, the taxonomies and the function allocation recommendations to develop minimum information and control requirements. SMEs reviewed the recommendations. The work yielded a set of recommendations for control station considerations for minimum information elements for safe UAS operation in the NAS, as well as potential directions for future research.

UAS Crewmember Training and Certification: University of North Dakota (UND) performed a literature review with the objective of providing recommendations for Unmanned Aircraft Systems (UAS) crewmember training and certification minimum requirements for both pilot and visual observer. The scope of the recommendations was for UAS larger than 55 pounds and operations in both Visual Line Of Sight (VLOS) and Beyond Visual Line Of Sight (BVLOS). The review included existing CFRs, legislative material (public laws and acts), Advisory Circulars, the Aeronautical Information Manual, and FAA Orders, manuals, and policy statements. The team sought other federal agency and academic sources, including United States military sources and foreign research and regulatory efforts.

The review summarizes the content found in these various publications that focus on pilot and visual observer training and certification. The research team offers general and specific recommendations derived from the content and rationale provided in these sources.

Authorities have argued for having existing manned FAR Part 61 subjects included in future UAS pilot training syllabi. Regulators could add topics unique to UAS, and delete those topics with no application to UAS. The team found more diversity in material and research related to pilot certification. Some sources put in place, or recommended, multiple levels of pilot certification, while others recommended fewer. To accommodate the demands of BVLOS and positive control, researchers commonly recommend an instrument rating.

Very few sources focused on visual observer training and certification. This may be due to the expected operating environment of UAS, which envisions higher operating altitudes and operations BVLOS.

VO Training and Certification: New Mexico State researched how to train and certify UAS VOs in three phases. In Phase 1, the team conducted in-depth interviews with SMEs and surveyed UAS community members. Participants stated that visual observers must be able to scan the airspace effectively, track aircraft, and make accurate and reliable estimates of (relative) aircraft position, assess the need for a potential avoidance maneuver, and communicate that need to the UAS pilot in a timely manner.

In Phase 2, researchers conducted field studies of VOs and other UAS crewmembers during a UAS flight test conducted at a non-towered airport in Las Cruces, NM. The findings confirmed Phase 1 findings: visual observers rely on a combination of visual perception, communication, and team coordination skills to assist pilots in effectively accomplishing see-and-avoid duties during UAS operations.

In Phase 3, the researchers conducted a broad NAS stakeholder survey that focused on two pivotal issues: Should visual observers receive formal training, and should visual observers be required to pass an exam? Participants were approximately evenly split on the need for formal classroom/online and hands-on training. Furthermore, participants favored having to pass a formal classroom/online exam (although the trend was not quite statistically significant), whereas, participants were generally against a formal practical exam.

The research team suggests that licensed manned/unmanned aircraft pilots should not require any additional training or certification to act as visual observers in UAS operations, regardless of platform weight. On the other hand, previously unlicensed persons who would like to serve as visual observers can rely on existing print/online materials for training and regulators should certify them with a process similar to what the FAA is currently using for Part 107 licensure.

Final Report: The ASSURE team will deliver the final report in December 2017.

Name & Origin of All Research Personnel

Name	Origin
Ellen Bass (PI)	USA
Philip Smith (Institutional PI)	USA
John Bridewell (Institutional PI)	USA
Igor Dolgov (Institutional PI)	Russian Federation
Carl Pankok, Jr.	USA
Douglas Lee	USA
Ali Jazayeri	Iran
Zachary Waller	USA
Scott Kroeber	USA
R. Richard Ferraro	USA
Thomas Petros	USA
Paul Cline	USA
Amy Spencer	USA
Ernest Anderson	USA
Robert Concannon	USA
Joel Walker	USA
David Claudio	Puerto Rico

Graduation Dates of Students

Name	Graduation Date
Ali Jazayeri (DU)	Spring 2020
Amy Spencer (OSU)	Spring 2018
Joel Walker (Montana MSU)	Spring 2021

Placement of Previous Research Students

Name	Placement
N/A	N/A

Human Factors of UAS Procedures & Control Stations

Embry-Riddle Aeronautical University led a large team, Drexel University, Kansas State University, Mississippi State University, The Ohio State University, University of North Dakota, Montana State University, University of Alaska – Fairbanks, and New Mexico State University, in developing recommendations for minimum unmanned aircraft system (UAS) control station standards and guidelines, and pilot procedures and operational requirements. The recommendations focused on the operation of fixed-wing unmanned aircraft (UA) larger than 55 lbs. operated Beyond Visual Line Of Sight in an integrated National Airspace System (NAS) for class G, non-towered airports, and low-activity class D airports. The research approach included (1) development of recommendations for minimum human-automation function allocation, (2) identification of minimum information requirements for safe UAS operation in the NAS, (3) storyboard development and a cognitive walkthrough of the storyboards, (4) development of recommendations for control station ergonomics and environment, and (5) produce recommended minimum pilot procedures and operational requirements.

Human-Automation Function Allocation: The ASSURE team expanded upon previous work and conducted a task analysis of taxi, takeoff, landing, navigation, communication, contingency, and handover tasks to guide function allocation recommendations for UAS during these operations. For each, the researchers recommended a minimum functional allocation, identified potential high and/or lower levels of automation, and recommended an autonomous mode (which the team recommends as a required mode to mitigate risk of lost command and control link situations). The research team refined these recommendations based on subject matter expert (SME) review. SMEs had backgrounds in UAS and traditional manned aircraft operations. Except for lost link, SMEs indicated that UAS pilots can accomplish the tasks necessary to operate the UAS safely in the NAS with regulations similar to those for manned operation (i.e., substantial automation assistance is not required as compared to manned aircraft operation).

UAS Control Station Information Requirements: The ASSURE research team developed recommendations to support control station standards and guidelines. Informed by the function allocation recommendations and a literature review, the team created a database of potentially necessary information elements. To categorize these elements, researchers created two taxonomies: one reflecting the level of availability of the information element; and the other identifying the agent(s) with control over changing the element. With the aid of SMEs, the researchers developed recommendations for control station standards and guidelines for minimum information elements necessary for the safe UAS operations in the NAS.

Storyboards: The ASSURE team then developed storyboards for three scenarios: (1) UAS departing from and arriving to the same airport with low traffic volume, (2) UAS diversion to an alternate airport with low traffic volume, and (3) a ferry UAS operation departing from one airport and arriving at another airport with low traffic volume. These storyboards detailed the steps necessary to transition the system from its initial state to the goal state. Using these storyboards, the ASSURE researchers and SMEs did cognitive walkthroughs and, in a collaborative process, refined their recommendations.

Ergonomics, Environments, and Mobility Considerations: The ASSURE research team identified UAS control station considerations regarding its ergonomics, work environment and special considerations to address control station mobility. The team surveyed UAS control station design specific literature supplemented with existing workstation design literature. The researchers surveyed/interviewed SMEs about design features not adequately addressed in the literature. This work produced minimal physical control station design recommendations to promote favorable operator comfort and performance and reduce musculoskeletal injury risks.

Key Findings and Recommendations:

- UAS pilots can operate UAS in the NAS with comparable function allocation strategies, automation, and information requirements to manned operations.
- A major difference between manned and unmanned operations is the use of visual observers for collision avoidance during taxi, takeoff, climb-out, approach, and landing.
- Additional recommendations identified types of information displayed at the control station for unmanned operations:
    - Presentation of obstacle information when flying close to the ground and for ground operations, including a dynamic surface display with overlaid ownship position during taxi, takeoff, and landing;
    - Presentations of terrain information; and
    - Presentation of altitude above ground level.
- Other differences involving contingency operations unique to unmanned operations:
    - Lost command/control link;
    - Degraded unmanned aircraft (UA) position reporting;
    - Loss of contingency flight planning automation when UA is airborne;
    - Loss of communications with the visual observer; and
    - Unique procedures associated to hand over control of UA from one control station to another during flight.
- Despite a lack of UAS-specific control station ergonomics, environment, and mobility literature, the team's research determined:
    - Fixed location control stations mirror general office environments, but some features need further attention: chair design, monitor orientation, etc.;
    - Glare and vibration are significant concerns resulting from mobility; and
    - Pilot SME interpretation of "good" control station ergonomic and environment design varies based on the size of past UAS flown and level of experience.
- The team developed, validated, and verified four (4) pilot and 46 operational minimum recommended procedures based upon the UAS operational scope of the project.

Final Report: The final report is available on the ASSURE website: www.ASSUREuas.org.

Name & Origin of All Research Personnel

Name	Origin
Richard S. Stansbury (PI)	USA
Ellen Bass (institutional PI)	USA
Joel Walker (institutional PI)	USA
Kurt Carraway (institutional PI)	USA
Zach Waller (institutional co-P)	USA
Paul Snyder (institutional co-PI)	USA
Phil Smith (institutional PI)	USA
Andrew Shepherd (institutional PI)	USA
Joseph E. Millette (institutional PI)	USA
Bradley Brown (institutional PI)	USA
Kari Babski-Reeves	USA
Joe Cerreta	USA
Ronald Storm	USA
Carl Pankok	USA
Henry M. Cathey, Jr.	USA
David Claudio	USA
Timothy Bruner	USA
Reuben Burch	USA
Amanda Brandt	USA
Gary Ullrich	USA
Ali Jazayeri	Iran
Andrew Abbate, USA	USA
Amy Spencer	USA
Travis Balthazor	USA
Andrea Meyer	USA
Nicholas C. Adkins	USA
Catherine F. Cahill	USA
Robert T Parcell	USA
Joseph A. Rife	USA
Andrew C. Wentworth	South Africa
Matthew J. Westhoff	USA
Todd Simpson	USA
John Bridewell	USA
James Higgins	USA
Ernest Anderson	USA

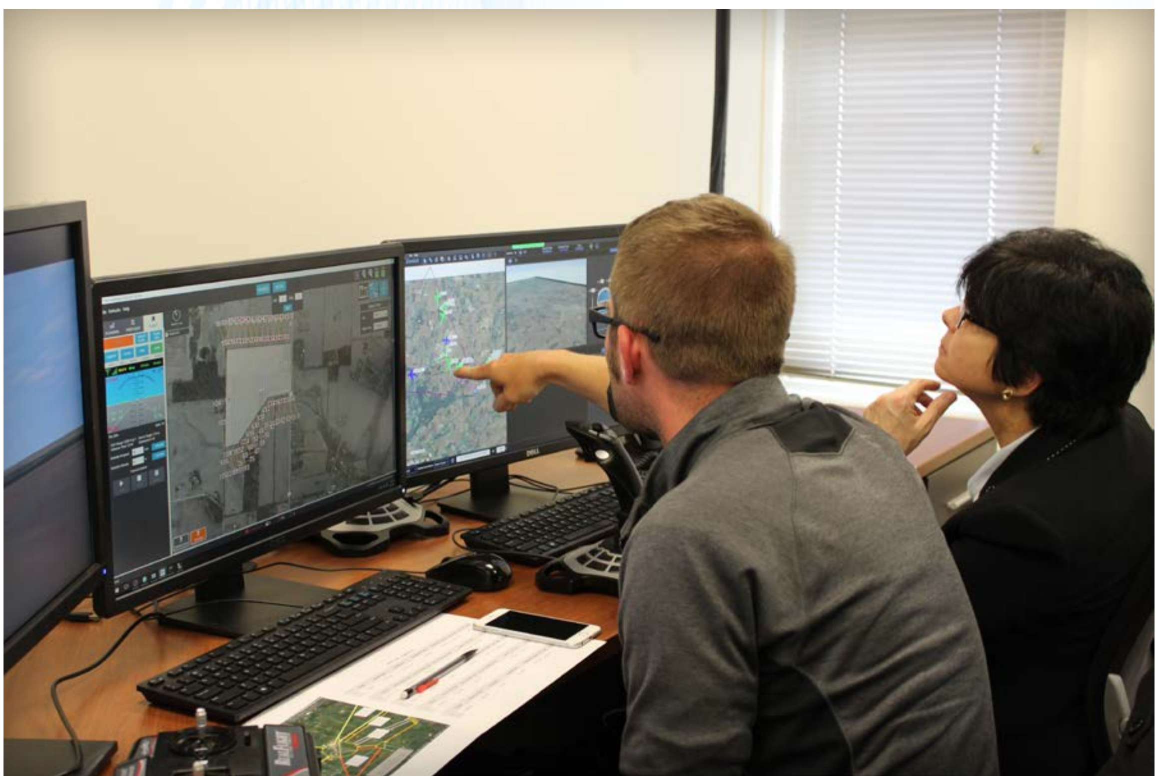
William Watson	USA
Thomas Petros	USA
Richard Ferraro	USA
Scott Kroeber	USA

Graduation Dates of Students

Name	Graduation Date
Joel Walker (Montana MSU)	Spring 2021
Ali Jazayeri (DU)	June 2020
Amy Spencer (OSU)	Spring 2018
Eboni Smith (Mississippi MSU)	Spring 2019
John H. Debusk (Mississippi MSU)	Summer 2018
Farjana Nur	Summer 2018

Placement of Previous Research Students

Name	Placement
N/A	N/A



TRAINING

Research Focus Lead: Kansas State University

The FAA expects a substantial increase in air traffic below 400 feet, with the integration of small unmanned aircraft systems (sUAS) in the NAS also significantly raising the exposure of the general population to the potential effects of an sUAS mishap.

ASSURE Team Capabilities
All institutions offering UAS coursework have established records in FAA aeronautical training, including air traffic control, and are holders of the FAA 141 and 147 Training School Certificates.

Research Focus

- The creation of crewmember training and certification requirements based on instructional system design theory and methods
- Recommendations for training and certification requirements for aircrew and ground crew members toward the safe and efficient integration into the NAS juxtaposed to current manned requirements
- Investigating the recommended training and certification requirements to assist with see-and-avoid in a manner that optimally mitigates the risk of conducting civil UAS operations

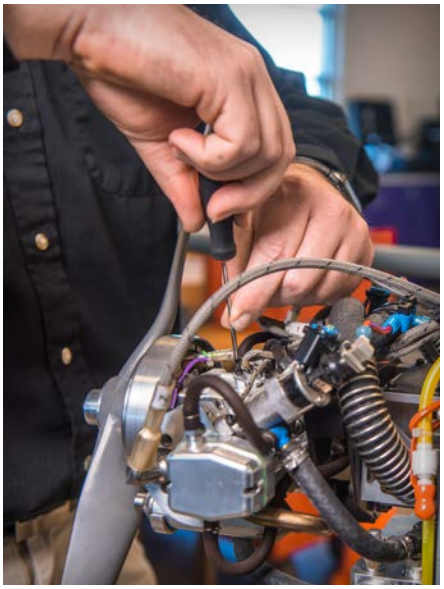
Current Research & Results

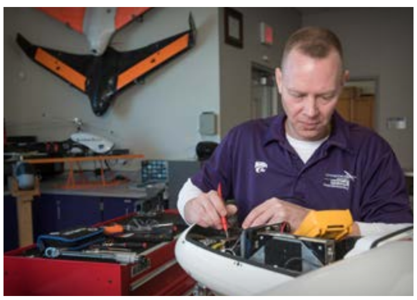
UAS Maintenance, Modification, Repair, Inspection, Training, and Certification

Purpose: The Unmanned Aircraft System (UAS) industry continues to enjoy rapid growth toward full and seamless airspace integration, creating the need for this research project, which is to assist the Federal Aviation Administration (FAA) in safely integrating this new technology into the National Airspace System (NAS). Kansas State University (KSU), Embry-Riddle Aeronautical (ERAU), Montana State University (MSU), and Northland Community Technical College (NCTC) conducted a two-year research project to identify the requirements and considerations for UAS maintenance, modification, repair, inspection, training, and technician certification by building upon the existing body of knowledge for sustaining UAS. The research team collected and consolidated current UAS practices from industry and developed recommended requirements to minimize the risks of maintenance-induced failures.

This final report summarizes all research activities:

- Performing a gap analysis between the current regulatory and operational states;
- Updating a prototype FAA UAS maintenance and repair database;
- Developing recommended technician certification requirements;
- Conducting air traffic simulations to understand the effects of maintenance-induced failures with operational impact analysis;
- Providing process recommendations for FAA aviation safety inspectors and commercial repair stations as they integrate this technology into their training and operational environments;
- Making recommendations for UAS maintenance-related accident reporting requirements.





Approach and Findings: The research team conducted a gap analysis comparing the current state of the UAS industry with the three most relevant FAA regulations (14 Code of Federal Regulations [CFRs] Parts 43, 65, and 147). To accomplish this gap analysis, the team conducted four in-depth analyses to identify the maintenance technician skills required for unique UAS considerations: non-metallic materials, communication links, control stations and support equipment, software and autopilots. These in-depth analyses identified 29 UAS-specific skills that need to be accounted for in future regulations. Researchers proposed that regulators segment these skills into a 3-tier skill classification system. The skill level is determined by the competences and skills required, which varies depending on system complexity. Ultimately, the ASSURE team proposed requirements to bridge the gaps in the 14 CFR Parts 43, 65, and 147.

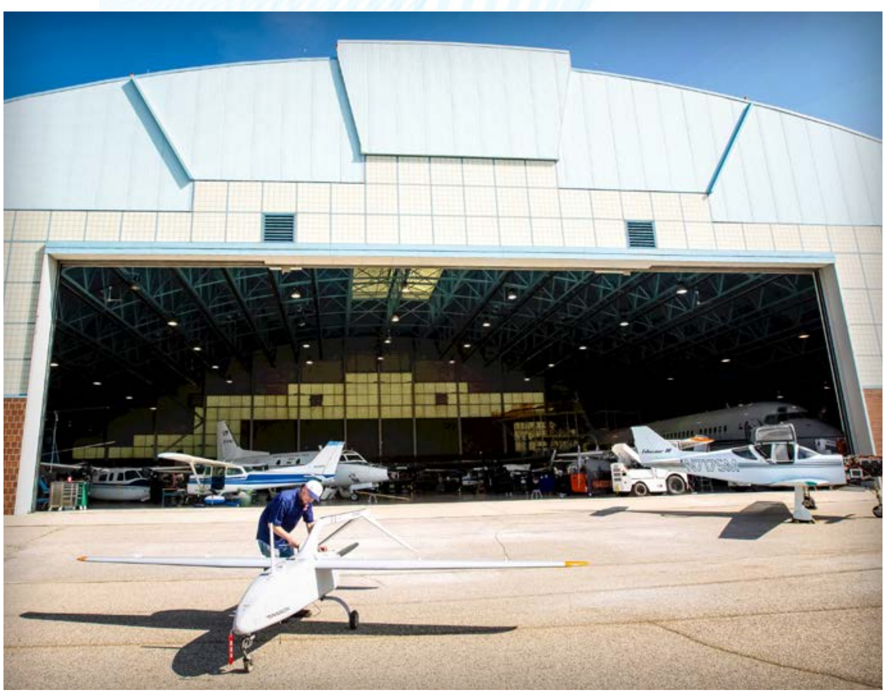
Researchers also recommended that all 29 UAS skills be included in the FAA Aviation Safety Inspector's (ASI) familiarization training using the same 3-tier skill classification methodology. The team also proposed changes to 14 CFR Part 145 (repair stations) to add new UAS technician ratings (§ 145.59) as well as segregation requirements for UAS parts and materials.

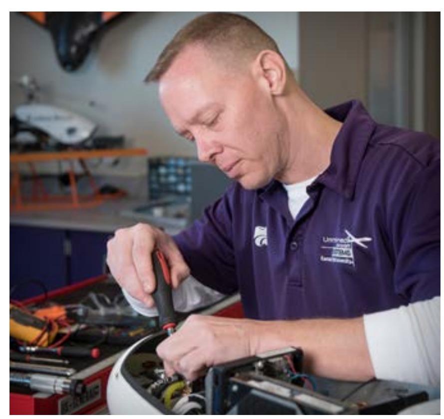
The research team found that vehicle and system reliability information is not publicly available through the Maintenance & Repair (M&R) database; most organizations utilize a logbook system containing daily flight data as well as incident information. The research team analyzed manned and unmanned accident databases and recommended that regulators expand the Aviation Safety Information Analysis and Sharing (ASIAS) program to serve as the centralized repository for UAS information as well.

The ASSURE team conducted Air Traffic Control (ATC) simulations of 42 maintenance-induced failure scenarios and found that incidents over populated areas occurred 14% of the time. This highlights an urgent need for UAS maintenance technician certification to ensure safe operations in the national airspace (NAS). The research team recommended the creation of indicators for the UAS operator to detect and resolve operational failures. Finally, the ASSURE team proposed that regulators establish best practices for ATC personnel handling of emergencies and that pilots file UAS contingency flight plans before flight.

Name & Origin of All Research Personnel

Name	Origin
Dr. Kurt Barnhart	USA
Andi Meyer	USA
Stephen Ley	USA
Caleb Scott (student)	USA
Dr. Michael Most	USA
Dr. Doug Cairns	USA
Kyle Rohan (student)	USA
Femi Ibitoye (student)	Nigeria
Taylor de Man (student)	USA
Dr. John Robbins	USA
Mitchell Geraci	USA
Richard Stansbury	USA
Kimberly Bracewell (student)	USA
Tom Haritos	USA
Benjamin Griffith (student)	USA
Russel Gillespie (student)	USA
Paul Carlson (student)	USA
Charles Nick	USA





Graduation Dates of Students

Name	Graduation Date
Kyle Rohan (Montana MSU)	Spring 2019
Femi Ibitoye (Montana MSU)	Fall 2017
Taylor de Man (Montana MSU)	Fall 2017
Caleb Scott (KSU)	Spring 2018
Kimberly Bracewell (ERAU)	TBD
Paul Carlson (ERAU)	Spring 2018
Benjamin Griffith (ERAU)	Spring 2018
Russel Gillespie (ERAU)	Spring 2018

Placement of Previous Research Students

Name	Placement
Taylor de Man	Vans Aircraft (anticipated, Dec. 2017)

MINORITY OUTREACH

Lead: New Mexico State University

The FAA and its COE for UAS have a strong desire to incorporate Science, Technology, Engineering, and Math (STEM) outreach to students from groups who are underrepresented in STEM fields.

ASSURE Team Capabilities
STEM and Minority outreach is important to all our universities and provides opportunities for our industry partners to contribute to their local communities and to emphasize STEM, which is so critical to UAS design, manufacturing, operations, and maintenance.

Focus

- Performance of K-12 students in math and science

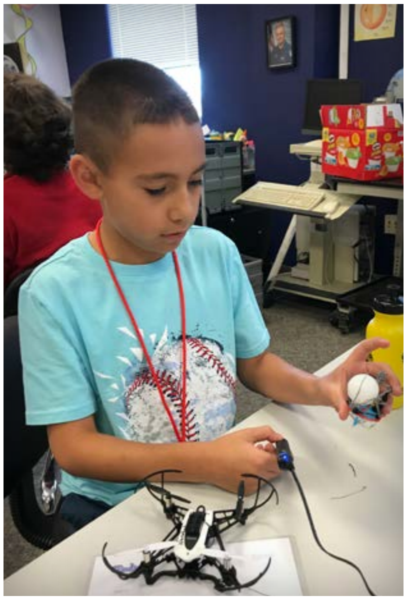
Project-based, student engagement, and active learning opportunities designed to enhance teamwork, communication skills, and understanding of the application of STEM in real life.

Current Efforts & Results

STEM Education Using UAS as the Central Learning Platform
Within the framework of the Federal Aviation Administration (FAA) Unmanned Aircraft Systems (UAS) Center of Excellence (COE), there is a strong desire to incorporate Science, Technology, Engineering, and Math (STEM) Outreach for students in groups who are underrepresented in STEM fields. There is no one, single approach that addresses STEM outreach for students of different ages or backgrounds, or those who have different cultural and regional influences. The ASSURE team used common technical ideas and instructional approaches as building blocks, which they tailor to the various underrepresented target groups.

The FAA proposed and funded, "UAS as a STEM Minority Outreach Learning Platform for K-12 Students," as an initial approach. The objective of the overall project was to provide two STEM Outreach approaches to the FAA that use UASs as the central learning platform. The target of this outreach is minority or underserved students. The two universities tasked with this UAS outreach are Tuskegee University, which can reach a predominantly African American student population, and New Mexico State University (NMSU), which can reach predominantly Hispanic and Native American student populations.

The STEM topics included fundamental aviation and programming concepts and included unique UAS-related content. The ASSURE team conducted the outreach in two phases that included UAS Roadshows and summer camps. Educators designed the UAS Roadshows for broad community engagement. There were three UAS Roadshow events held at both locations for a total of six roadshow events. With these events, the ASSURE team reached more than 1,000 students, providing hands-on activities, aviation education, flight demonstrations, UAS displays, lectures, flight simulator time, student UAS flights with a trained pilot, and more. Presenters highlighted aviation and FAA careers all within the context of flight safety as a central theme. These were very successful outreach activities.




UAS
Unmanned Aerial Systems


N130PV
EXIT

The ASSURE team's goal for these activities was to provide background knowledge, teach skills, and then build upon those skills. The UAS summer camps took advantage of the materials developed for the UAS Roadshows. A blend of the various elements that were part of the summer camps at the two locations included the following:

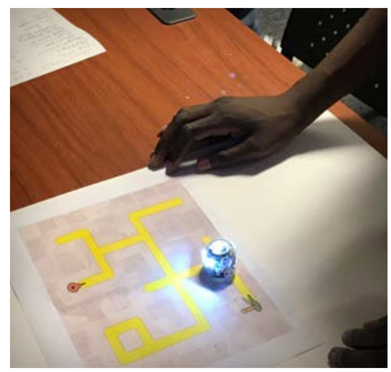
Physics of Flight – education, paper airplanes, etc.	UAS speakers on work and career
Smoke Tunnel demonstrations	Team Research Project – UAS Mission Design
UAS uses, education, and careers	Collecting, Analyzing, and Interpreting data
Flight simulator time using fixed-wing & multi-copters	3D Printing of mission-specific tool, testing, and execution
Ground Drone Jumping Bots – free driving and programming	sUAS flight – professional pilot on buddy box with student
Flight Drone – free flying, programming, and obstacle course challenge	Tour of Flight Test Site – facilities, aircraft, support equipment, etc.

As an example of the curricula and the approach used at NMSU, the camp was broken down into ten elements that allowed the students to expand their understanding of aviation and UAS. The figure below shows all the camp elements in one visual.

Educators start students with aviation education and flight safety. The physics of flight lessons are transferable into time flying fixed-wing and rotary aircraft on the flight simulator. The students then free-drive using Parrot Sumo ground bots. They then program the vehicles for a set obstacle course, and then are given a payload challenge assignment where a payload must be carried using their own 3D printed solution. Instructors use the ground bots to teach all necessary skills, first using a vehicle that is much more tolerant to accidents and the trials that come with new operator skills.

With a much better command of the skills needed to operate a remote vehicle, students repeated the same three steps using a Parrot Mambo drone – free flight, programming to fly through an obstacle course, and a payload challenge. The ASSURE team used this crawl-walk-run strategy on a ground vehicle first and then employed it very successfully on the more delicate flight vehicles. The students had much more control and skill when it came time for the camp's flight activities. A visit to the NMSU Physical Science Laboratory's UAS Test Site was a good opportunity to talk with professionals in STEM-related careers. These discussions helped the students imagine themselves in these careers in the future, and to see real-life flight vehicles, hardware, and support systems. The final camp day was a combined ground/flight challenge, putting their knowledge and skills to a test.

The Tuskegee "Camp Drop Zone" hosted 20 students in an all-day camp for one week. NMSU's "UAS Summer Camp" hosted 116 students in four camps that ran for two weeks, each in half-day sessions.



Name & Origin of All Research Personnel

Name	Origin
Henry M. Cathey, Jr. (NMSU)	USA
Joe Millette (NMSU)	USA
Susan Brown (NMSU)	USA
Nicole Delgado (NMSU)	USA
Heidi Sanchez (NMSU)	USA
Kassi Simpson (NMSU)	USA
Roshani Rajbanshi (NMSU)	Indonesia
Laura Martinez (NMSU)	USA
Kelsey Moore (NMSU)	USA
Mason Meier (NMSU)	USA
Gay Lenzo (NMSU)	USA
Timothey Lower (NMSU)	USA
Michael Brown (NMSU)	USA
Drew Sander (NMSU)	USA
Mohammad Jayed Kahn (Tuskegee U)	USA
Chadia Affane Aji (Tuskegee U)	USA
Bruce Heath (Tuskegee U)	USA
Suzie Stenson (Tuskegee U)	USA
Syed Firasat Ali (Tuskegee U)	USA
Ovaisullah Khan (Tuskegee U)	Pakistan
Sharana Basaweshwara Asundi (Tuskegee U)	India

Graduation Dates of Students

Name	Graduation Date
N/A	N/A

Placement of Previous Research Students

Name	Placement
N/A	N/A

PUBLICATIONS, PROCEEDINGS & FUTURE RESEARCH

SIGNIFICANT EVENTS

Significant Events	Date
UAS Center of Excellence (COE) Selection announced by FAA Administrator Huerta	May 2015
UAS COE Kick-Off Meeting	June 2015
Initial research grants awarded	September 2015
ASSURE – FAA Program Management Review, Santa Fe, NM	December 2016
ASSURE Meeting of its Industry Partners in Santa Fe, NM	December 2016
ASSURE A3 sUAS Ground Collision Study Peer Review, FAA HQ, Washington, DC	February 2017
ASSURE attend and support FAA UAS Symposium, Reston, VA	March 2017
ASSURE – FAA Program Management Review, Reston, VA	March 2017
ASSURE A3 sUAS Ground Collision Study Public Release & Media Event, Washington, DC	April 2017
ASSURE XPONENTIAL 2017 Panel, Dallas, TX	May 2017
ASSURE Meeting of its Industry Partners in Dallas, TX	May 2017
ASSURE A4 sUAS Airborne Collision Study Peer Review, Washington, DC	May 2017
ASSURE Attends Paris Airshow, France	June 2017
ASSURE – FAA Program Management Review, UC-Davis, CA	August 2017
ASSURE Visit & Meetings with Israel MOT & CAAI, Tel Aviv, Israel	September 2017
ASSURE Attend UAS Standardization Collaborative Kickoff, Washington, DC	September 2017

JOURNAL ARTICLES

- sUAS Ground Collision Severity: Arterburn, D., Duling, C., and Goli, N., "Ground Collision Severity Standards for UAS Operating in the National Airspace System (NAS)," 17th AIAA Aviation Technology, Integration, and Operations Conference, AIAA AVIATION Forum, (AIAA 2017-3778)

CONFERENCE PROCEEDINGS

- Airborne Collision Severity Update Briefing to the FAA and Members of the National Institute for Aviation Research Laboratories, January 2016
- Airborne Collision Severity Support to the Small UAS Group Committee, Washington, DC, March 2016
- Airborne Collision Severity Update Briefing to Association for Unmanned Vehicle Systems International (AUVSI) XPONENTIAL 2016, May 2016
- Airborne Collision Severity Update Briefing to Association for Unmanned Aircraft Systems Technical Analysis and Applications Center (TAAC) XPONENTIAL 2016, December 2016
- Project A3: Airborne Collision Severity Update Briefing to Association for Unmanned Vehicle Systems (AUVSI), Spain, February 2017
- UAS Human Factors: Pankok, C. & Bass, E.J. (2017). "ASSURE Research Project: UAS Human Factors Considerations," The Third Annual Unmanned Systems Academic Summit, Dayton, OH, August 15, 2017
- sUAS Certification Project: ASSURE Research Panel at UAS Technical Analysis and Applications Center, Santa Fe, NM, December 2016
- sUAS Certification Project: FAA ASSURE Panel Presentation, UAS Midwest Conference, Dayton, OH, August 2017
- sUAS Certification Project: UAS Tech Forum Panel Presentations, "Leveraging the Power of Collaboration & Partnership to build a UAS Industry" and "The Future of UAS in Oklahoma and Kansas – Making Oklahoma and Kansas the Center of the UAS Industry," Oklahoma City, OK, September 2017
- sUAS DAA BVLOS: Panel Discussion, TAAC Conference, December 2016
- sUAS DAA BVLOS: Flight Testing, Update Briefing to SARP, February 2017
- sUAS DAA BVLOS: DAA Research Focus Area, AUVSI XPONENTIAL 2017 ASSURE Fair, May 2017
- sUAS DAA BVLOS: DAA Research Focus Area, AUVSI XPONENTIAL ASSURE Industry Day, May 2017
- sUAS Ground Collision Severity: Presentation on Collision Severity to the National Academy of Science Committee conducting a study to evaluate the potential of probabilistic assessments of risks and other risk assessment methods for streamlining the process of integrating unmanned aircraft systems (UAS) into the national airspace system (NAS)NA
- Team ASSURE: FAA Expo, Reston, VA, March 2017
- Team ASSURE: Aterburn, D., Askelson, M., Cathey, H., Stansbury, R., Bass, E., Aldag, T., Carraway, K., & Snyder, K. (2017). "ASSURE Research and Outreach Fair," AUVSI XPONENTIAL 2017, Dallas, TX, May 8-11, 2017
- UAS MX, MOD, Repair & Training: DOE Blade Reliability Workshop (Repair techniques developed under A5 presented as field repairs for composite wind turbine blades – Doug Cairns), Albuquerque, NM, August 2016

2018 RESEARCH

Each of the ongoing research projects has identified knowledge gaps and needs for additional research. Below are the areas of research that the FAA appears most interested in funding, with its limited resources, at the time of the writing of this Annual Report. This is ASSURE's best guess; the priorities for future research supporting the mission to safely integrate UAS into the national airspace system (NAS) may change.

- Detect-and-Avoid Flight Testing and Evaluation
- STEM Minority Outreach to underserved communities
- sUAS Airborne Collision Severity (Phase II) – The FAA is currently scoping this project. This study will likely evaluate collisions with General Aviation aircraft and helicopters, as well as a study of boundary layer effects on collisions. Current planning for this project includes the development of a representative high-bypass turbofan engine models for the study of sUAS impacts.
- UAS E-Commerce study will include an analysis of the implications of emerging UAS operations, network and integration into the NAS.
- Stand-up UAS Safety Research Center

The ASSURE University Coalition

Assure has the knowledge of a 23 Member University Coalition

MISSISSIPPI STATE UNIVERSITY

UAF University of Alaska Fairbanks

The Ohio State University

UC Davis University of California

KU

The University of Alabama in Huntsville

Embry-Riddle Aeronautical University

NM State University

Kansas State University

WSU Wichita State University

OSU Oregon State University

Montana State University

NC State University

Auburn University

UND University of North Dakota

Drexel University

Université Concordia University

Tuskegee University

National UAS Training and Certification Center

Indiana State University

Louisiana Tech University

Technion Israel Institute of Technology

University of Southampton

The FAA's Center of Excellence for UAS Research

ASSURE

Alliance for System Safety of UAS through Research Excellence

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